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COMPASS Hadron Spectroscopy – Final states involving neutrals and kaons

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The COMPASS experiment at CERN is well designed for light-hadron spectroscopy with emphasis on the detection of new states, in particular the search for J^{PC} -exotic states and glueballs. We have collected data with 190 GeV/c charged hadron beams on a liquid hydrogen and nuclear targets in 2008/09. The spectrometer features good coverage by electromagnetic calorimetry and a RICH detector further provides π / K separation, allowing for studying final states involving neutral particles like π^0 or η as well as hidden strangeness, respectively. We discuss the status of ongoing analyses with specific focus on diffractively produced $(\pi^0\pi^0\pi)^-$ as well as $(K\bar{K}\pi)^-$ final states.

Keywords: light hadron spectroscopy; diffractive dissociation; spin-exotic mesons, hybrids

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1. Introduction

The existence of states beyond the constituent quark model (CQM) has been speculated about almost since the introduction of colour^{1,2}. Due to the gluon self-coupling via colour-charge, so-called hybrid mesons, $q\bar{q}$ states with an admixture of gluons, and glueballs, states with no quark content, consisting of (constituent) gluons only, are allowed within Quantum Chromodynamics. While light glueballs would not be observable as pure states, as they would mix with ordinary $q\bar{q}$ -mesons, hybrid mesons ($q\bar{q}g^n$) are promising candidates to search for resonances beyond the CQM. Especially, as the lowest mass candidate is predicted³ to have exotic quantum numbers of spin, parity and charge conjugation $J^{PC} = 1^{-+}$ not attainable by ordinary $q\bar{q}$ states, and a mass between 1.3 and 2.2 GeV/c². Two experimental 1^{-+} hybrid candidates in the light-quark sector have been reported in the past in different decay channels, the $\pi_1(1400)$ and the $\pi_1(1600)$. In particular the resonant nature of the $\rho\pi$ decay channel of the latter is highly disputed^{4,5}. COMPASS has started to shed new light on the puzzle by the observation of an exotic 1^{-+} signal in the 2004 data, consistent with the famous $\pi_1(1600)$; it shows a clean resonant behaviour⁶.

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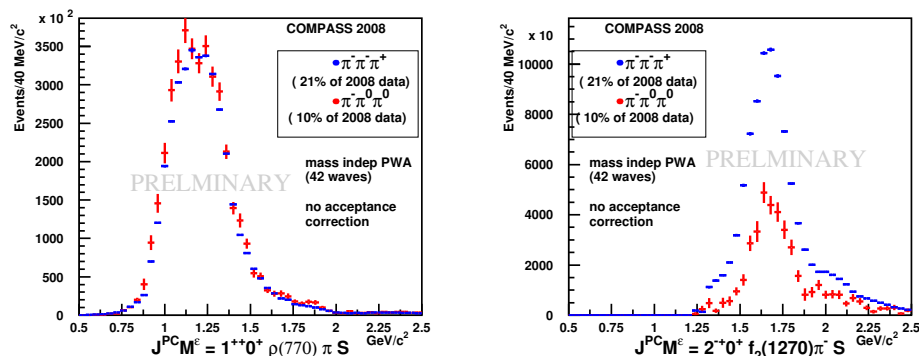


Fig. 1. Comparison of 3π analyses neutral vs. charged mode (2008 data): Exemplary intensities of main waves. For comparison, neutral and charge mode intensities are normalised to the well-established $a_2(1320)$ in the $2^{++}1^{+}[\rho\pi]D$ wave. *Left:* $1^{++}0^{+}[\rho\pi]S$ wave ($a_1(1260)$); *Right:* $2^{-+}0^{+}[f_2(1270)\pi]S$ wave ($\pi_2(1670)$).

The COMPASS spectrometer⁷ at the CERN SPS features electromagnetic calorimetry and a Ring Imaging Cherenkov detector. Photon detection in a wide angular range with high resolution is crucial for decay channels involving π^0 , η or η' , and the RICH allows for final state particle identification. A good separation of pions from kaons enables the study of kaonic final states. Not only production of strangeness with the pion beam can thus be studied but also kaon diffraction, using the incoming kaon beam. The COMPASS data taken in 2008/09 with a 190 GeV/c π/K or p beam provide thus excellent opportunity for simultaneous observation of new states in various decay modes within the same experiment. Moreover, the data contain subsets with different beam projectiles and targets, allowing for systematic studies not only of diffractive but also central production and Primakoff reactions.

2. First results on neutral and kaonic channels

An important cross-check of all analyses is the test for isospin symmetry in the observed spectra. The $\rho\pi$ decay channel of the $\pi_1(1600)$ for example, can be studied in two modes of 3π final states, $\pi^-\pi^+\pi^-$ (charged) and $\pi^-\pi^0\pi^0$ (neutral), respectively. Depending on the underlying isobars, the relative contribution should follow isospin conservation. This is shown in Fig. 1. A first, preliminary partial-wave analysis (PWA) of main waves in diffractively produced 3π events has been performed for both modes, for details see⁸. To compensate different statistics, the wave intensities shown are normalised to the well-known $\rho\pi$ decay of the $a_2(1320)$ to make them comparable. We find similar intensities for the $\rho\pi$ decay, whereas a suppression factor of two is observed for the wave decaying into $f_2\pi$ as expected due to the Clebsch-Gordon coefficients. Further ongoing analyses involving neutrals cover $\pi^-\eta$, $\pi^-\eta\eta$ (search for the $\pi_1(1400)$ and lightest 0^{++} glueball candidate) as well as $\pi^-\pi^-\pi^+\pi^0$, $\pi^-\pi^-\pi^+\eta$ and $\pi^-\pi^-\pi^+\pi^0\pi^0$ final states (accessible isobars: $f_1, b_1, \eta, \eta', \omega$), for which COMPASS has recorded significantly higher statistics with

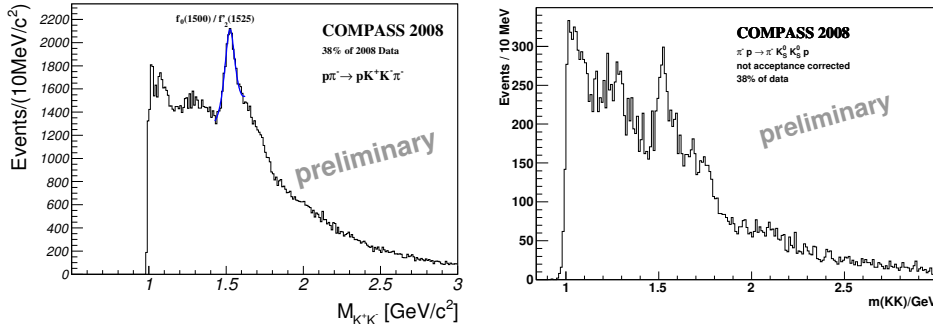


Fig. 2. Invariant mass spectra of $(K\bar{K}\pi)^-$ systems: (Left) K^+K^- (with $p_{K^-} \leq 30$ GeV/c) (Right) $K_s^0 K_s^0$.

respect to previous experiments, covering all spin-exotic meson decay channels in the light quark sector reported in the past.

Final states with strangeness are interesting for both, the glueball search in central production as well as diffractive production of hybrids. Exemplary we show the $K\bar{K}$ subsystems out of the $(K\bar{K}\pi)^-$ system again for two modes, $K^+K^-\pi^-$ and $K_s^0 K_s^0 \pi^-$ final states, respectively. Both spectra show a clear structure around the expected $f_0(1500)$, for details see⁹. Further ongoing analyses cover the $(K\bar{K}\pi)^0$ system as well as kaon diffraction into $K^-\pi^+\pi^-$ final states (PWA under preparation).

3. Summary & conclusions

COMPASS has collected data with high-intensity hadron beams (π^\pm, K^\pm, p) on nuclear and liquid hydrogen targets. The newly taken data sample exceeds the world data by a factor of 10-100, allowing to address open issues in light-mesons spectroscopy at good accuracy, even in the mass region beyond $2 \text{ GeV}/c^2$.

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